

(12) **United States Patent**  
**Ledvina et al.**

(10) **Patent No.:** **US 12,089,050 B2**  
(45) **Date of Patent:** **Sep. 10, 2024**

(54) **PAIRING DEVICES BASED ON DISTANCE**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)  
(72) Inventors: **Brent M. Ledvina**, San Francisco, CA (US); **Yannick L. Sierra**, San Francisco, CA (US); **Kyle C. Brogle**, San Francisco, CA (US); **Steven Andrew Myers**, San Jose, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)  
(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 44 days.

(21) Appl. No.: **18/145,793**  
(22) Filed: **Dec. 22, 2022**

(65) **Prior Publication Data**  
US 2023/0147041 A1 May 11, 2023

**Related U.S. Application Data**  
(63) Continuation of application No. 16/835,057, filed on Mar. 30, 2020, now Pat. No. 11,540,137.  
(Continued)

(51) **Int. Cl.**  
**H04W 12/50** (2021.01)  
**H04L 9/08** (2006.01)  
**H04L 9/32** (2006.01)  
**H04W 4/02** (2018.01)  
**H04W 12/037** (2021.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H04W 12/50** (2021.01); **H04L 9/0866** (2013.01); **H04L 9/32** (2013.01); **H04W 4/023** (2013.01); **H04W 12/037** (2021.01); **H04W 12/06** (2013.01); **H04W 12/64** (2021.01); **H04W 76/14** (2018.02); **H04W 4/80** (2018.02)

(58) **Field of Classification Search**  
CPC ... H04W 12/50; H04W 76/14; H04W 12/037; H04W 12/64; H04W 4/023; H04W 12/06; H04W 4/80; H04L 9/0866; H04L 9/32  
See application file for complete search history.

(56) **References Cited**  
U.S. PATENT DOCUMENTS

7,506,057 B2 3/2009 Bigioi et al.  
8,260,261 B2 9/2012 Teague  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102461128 A 5/2012  
CN 108291960 A 7/2018  
(Continued)

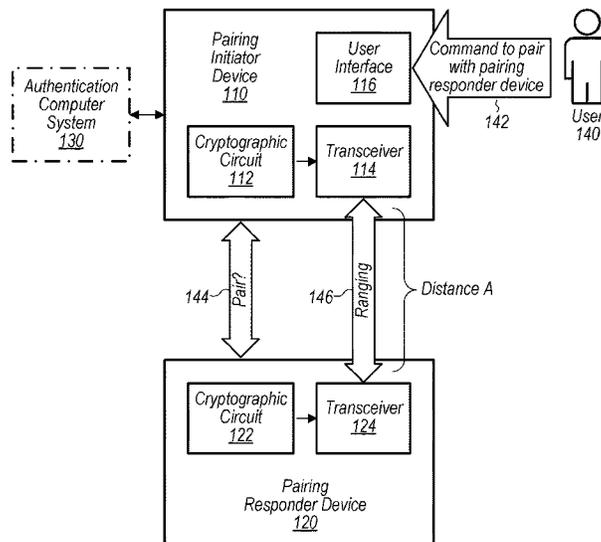
OTHER PUBLICATIONS

Office Action in Chinese Appl. No. 202080028916.1 mailed Dec. 29, 2023, 14 pages.  
(Continued)

*Primary Examiner* — Catherine Thiaw  
(74) *Attorney, Agent, or Firm* — Kowert, Hood, Munyon, Rankin & Goetzl, P.C.; Dean M. Munyon

(57) **ABSTRACT**  
Techniques disclosed herein relate to the pairing of a pairing initiator device and a pairing responder device for communication. The pairing initiator device and the pairing responder device range with each other to determine the distance between the pairing initiator device and the pairing responder device. Based on the distance being below a threshold distance, the pairing initiator device and the pairing responder device wirelessly pair with each other without further input from the user.

**20 Claims, 6 Drawing Sheets**



**Related U.S. Application Data**

(60) Provisional application No. 62/835,216, filed on Apr. 17, 2019.

2019/0014459 A1 1/2019 Zong  
 2019/0036688 A1 1/2019 Wasily  
 2019/0332787 A1 10/2019 Graf  
 2021/0045169 A1 2/2021 Pupakdee  
 2021/0211902 A1 7/2021 Achyuth

(51) **Int. Cl.**

**H04W 12/06** (2021.01)  
**H04W 12/37** (2021.01)  
**H04W 12/64** (2021.01)  
**H04W 76/14** (2018.01)  
**H04W 4/80** (2018.01)

FOREIGN PATENT DOCUMENTS

CN 108604129 A 9/2018  
 WO 2017181132 A2 10/2017

OTHER PUBLICATIONS

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,533,475 B2\* 9/2013 Frikart ..... H04L 63/061  
 713/169  
 8,823,494 B1 9/2014 Kovitz et al.  
 9,106,307 B2 8/2015 Molettiere et al.  
 9,621,603 B2\* 4/2017 Vadla Ravnas ..... H04L 12/1818  
 9,980,140 B1\* 5/2018 Spencer ..... H04W 12/02  
 10,382,203 B1 8/2019 Loladia et al.  
 10,796,563 B1 10/2020 Bell  
 11,843,693 B2\* 12/2023 Maim ..... G06F 21/87  
 2003/0220765 A1 11/2003 Overy et al.  
 2007/0300070 A1 12/2007 Shen-Orr  
 2011/0081860 A1\* 4/2011 Brown ..... G06F 21/35  
 455/41.3  
 2014/0134947 A1 5/2014 Stouder-Studenmund  
 2014/0181911 A1 6/2014 Kula  
 2014/0235171 A1 8/2014 Molettiere  
 2014/0380419 A1 12/2014 Peluso et al.  
 2016/0128114 A1 5/2016 Moy  
 2016/0241605 A1 8/2016 Taboriskiy  
 2016/0294822 A1 10/2016 George  
 2017/0201380 A1 7/2017 Schaap  
 2017/0359169 A1 12/2017 Benson et al.  
 2018/0139789 A9 5/2018 Agrawal  
 2018/0243573 A1 8/2018 Yoder  
 2018/0349585 A1 12/2018 Ahn et al.

Office Action in European Appl. No. 20723735.5 mailed Apr. 17, 2023, 8 pages.

Hugo Krawczyk, "SIGMA: the 'SIGn-and-MAC' Approach to Authenticated Diffie-Hellman and its Use in the IKE Protocols," Conference: Advances in Cryptology—CRYPTO 2003, 23rd Annual International Cryptology Conference, Aug. 17-21, 2003, 32 pages.

International Search Report and Written Opinion in PCT Appl. No. PCT/US2020/028174 mailed Jul. 22, 2020, 11 pages.

Yasir Arfat Malkani, Dan Chalmers, Ian Wakeman "A Framework for Secure Device Pairing by Demonstration of Physical Proximity," 2010 ACM, 6 pages (Year: 2010).

Kevin Curran, Amanda Millar, Conor McGarvey "Near Field Communication," International Journal of Electrical and Computer Engineering (IJECE) vol. 2, No. 3, Jun. 2012, pp. 371-382 (Year: 2012).

Meng Zhang, Anand Raghunathan and Niraj K. Jha "Trustworthiness of Medical Devices and Body Area Networks," 2014 IEEE vol. 102, No. 8 1174-1188 (Year: 2014).

Guo et al., "Distance-Based Encryption: How to Embed Fuzziness in Biometric-Based Encryption," IEEE Transactions on Information Forensics and Security, vol. 11, No. 2, Feb. 2016, 11 pages.

Zhang et al., "A Safe Authorization-Accelerating System based on NFC Wireless Communication and Connection," Secure and Reinforced NFC Wireless Communication Connection Authentication Acceleration System, released Nov. 10, 2013, 5 pages.

\* cited by examiner

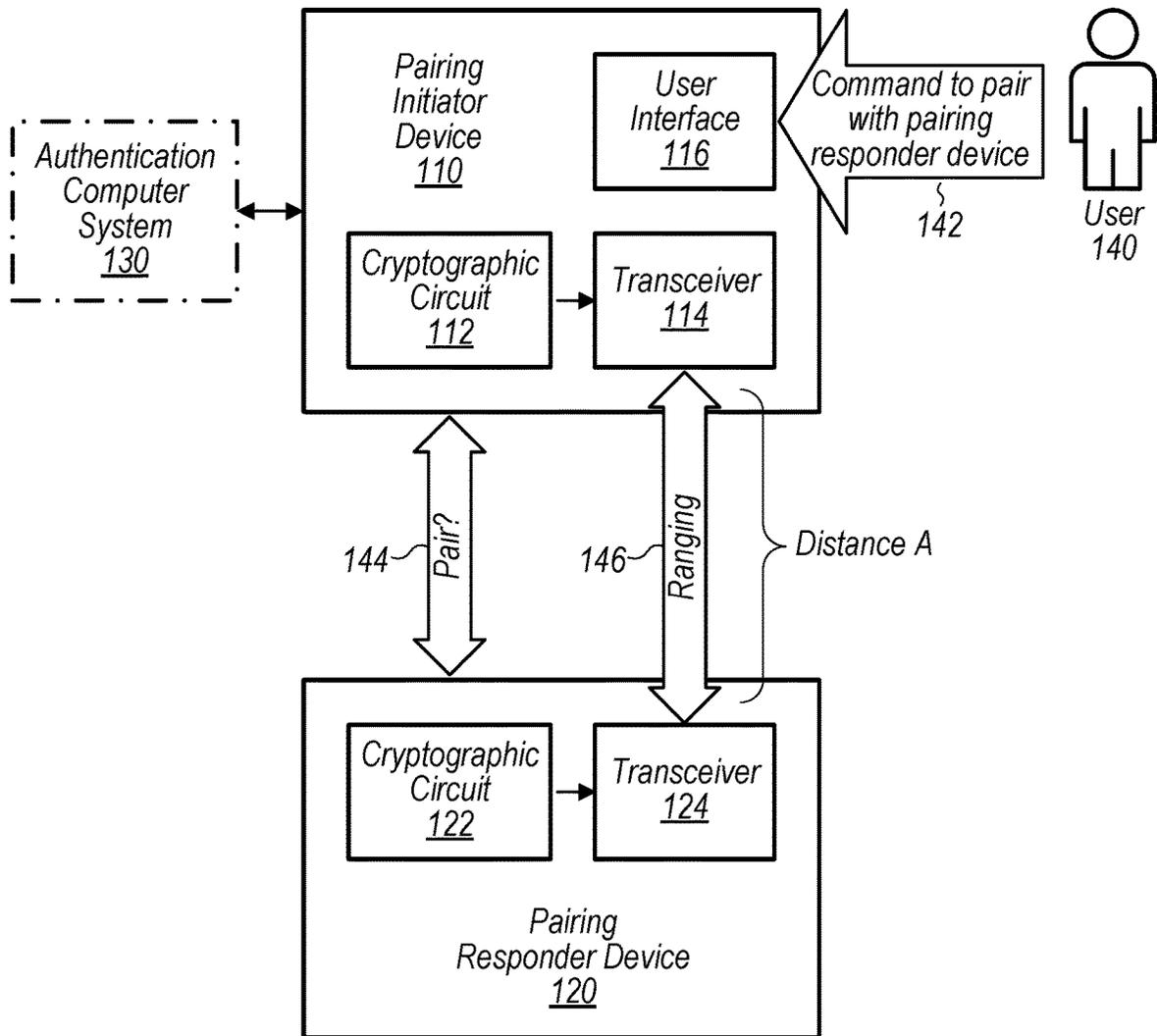


FIG. 1

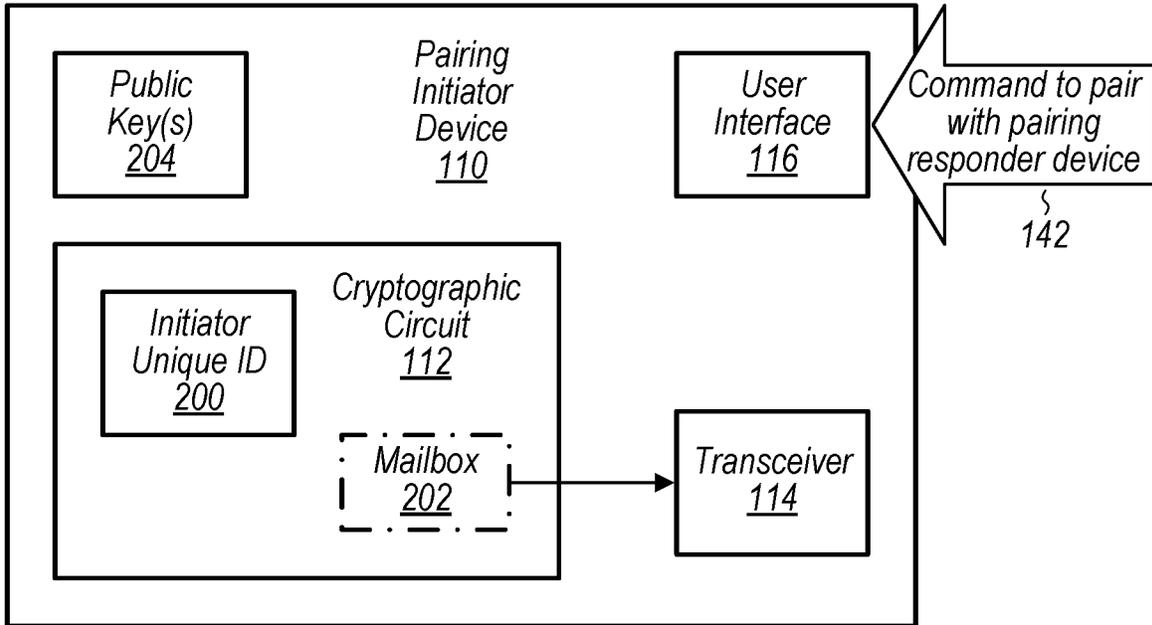


FIG. 2

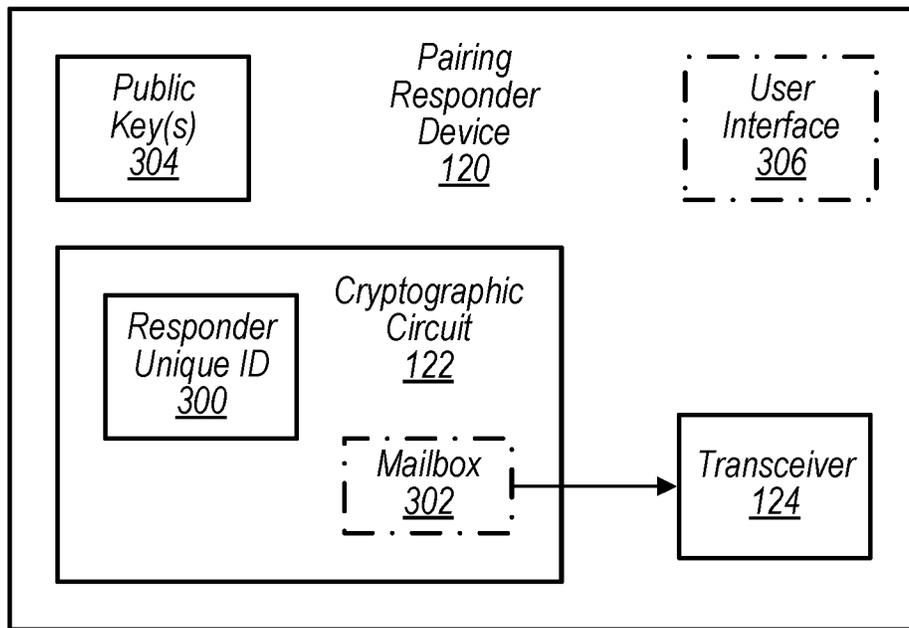


FIG. 3

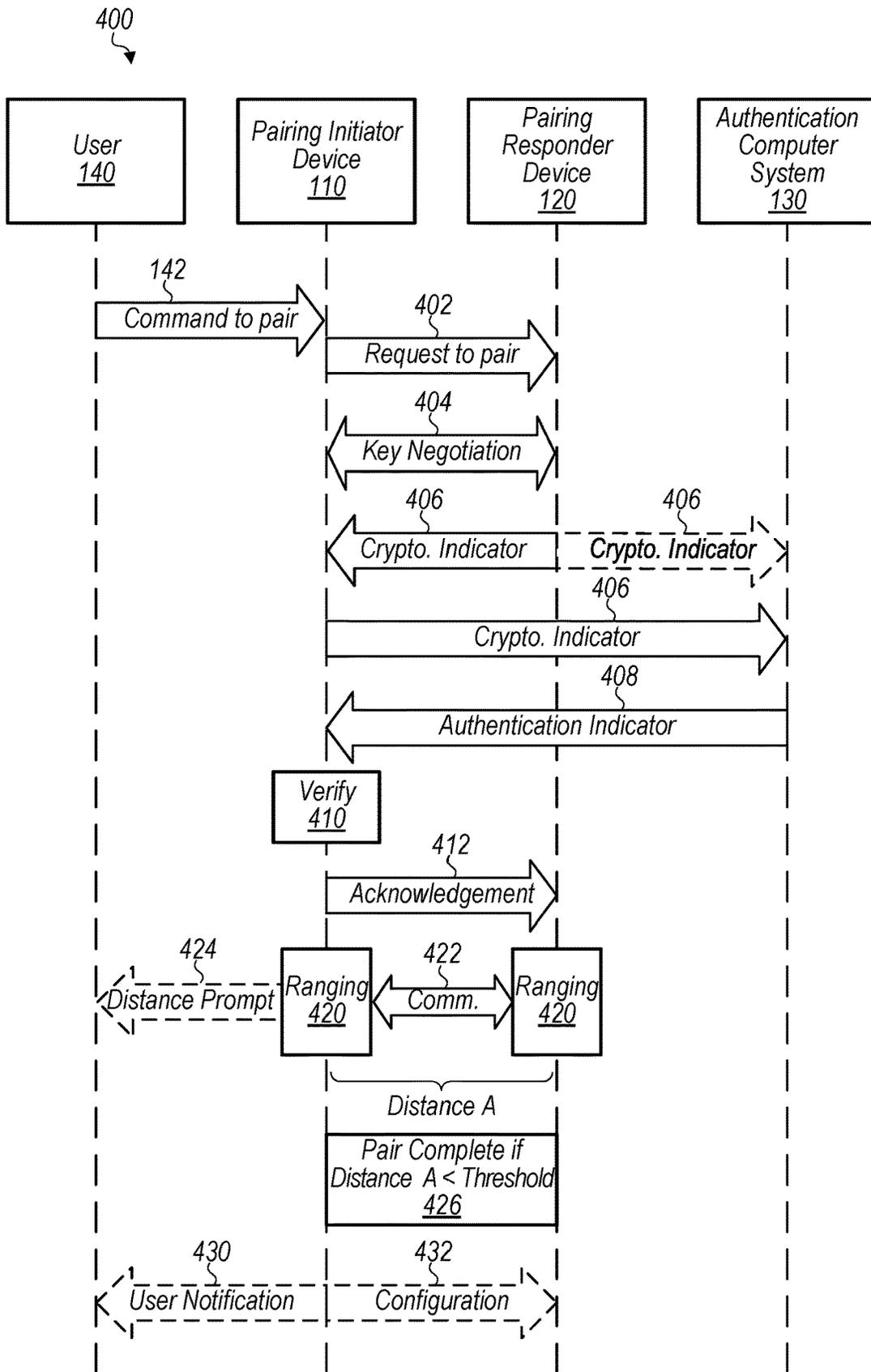


FIG. 4A

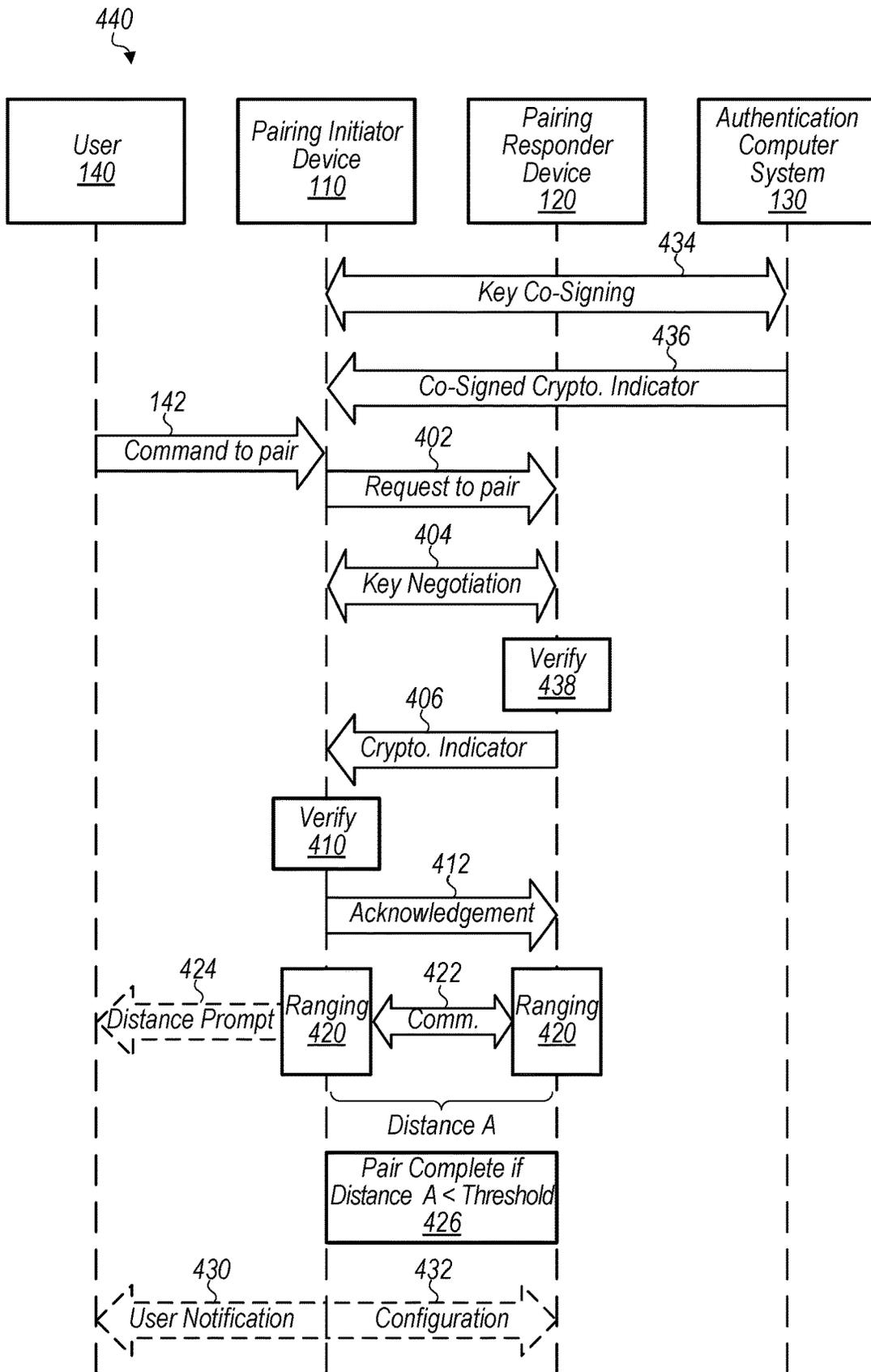


FIG. 4B

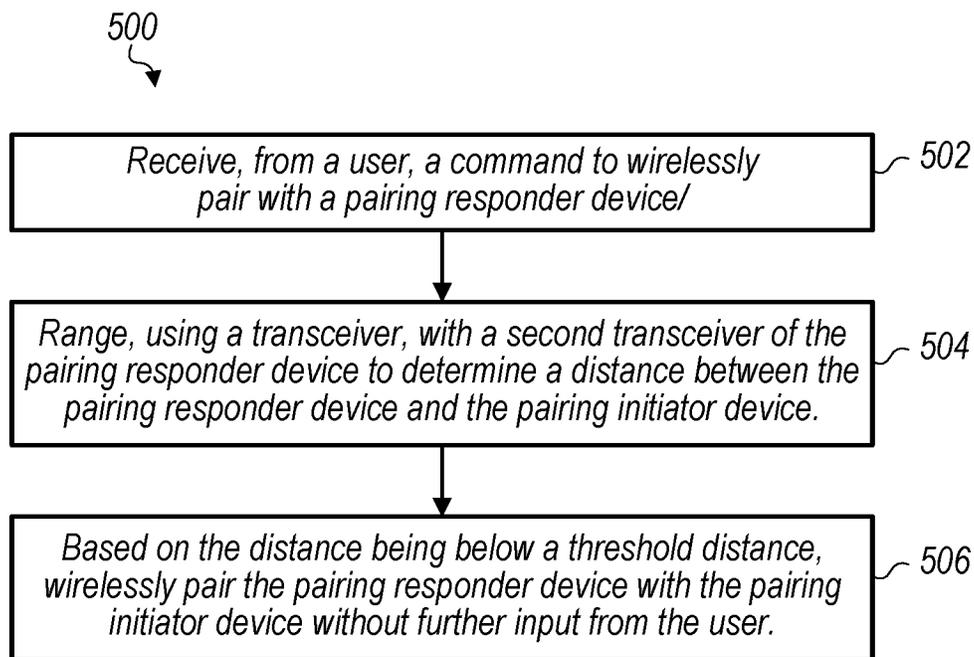


FIG. 5

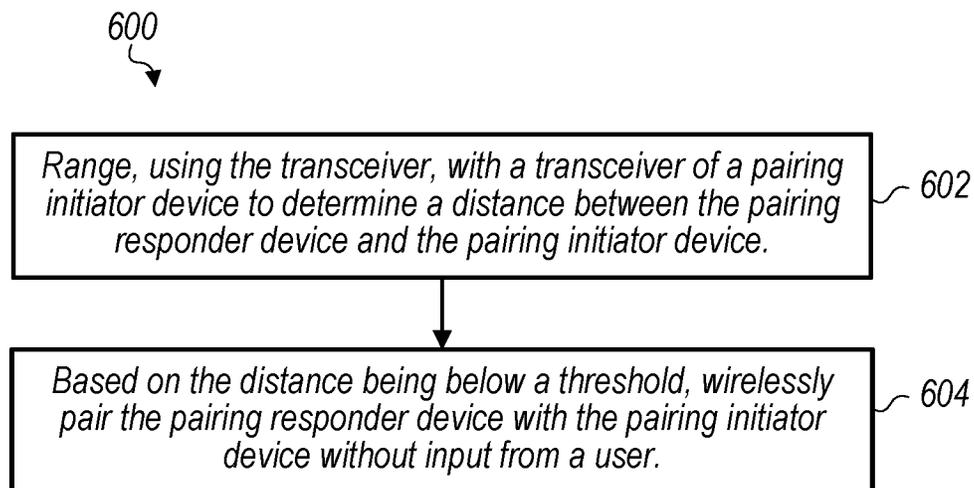


FIG. 6

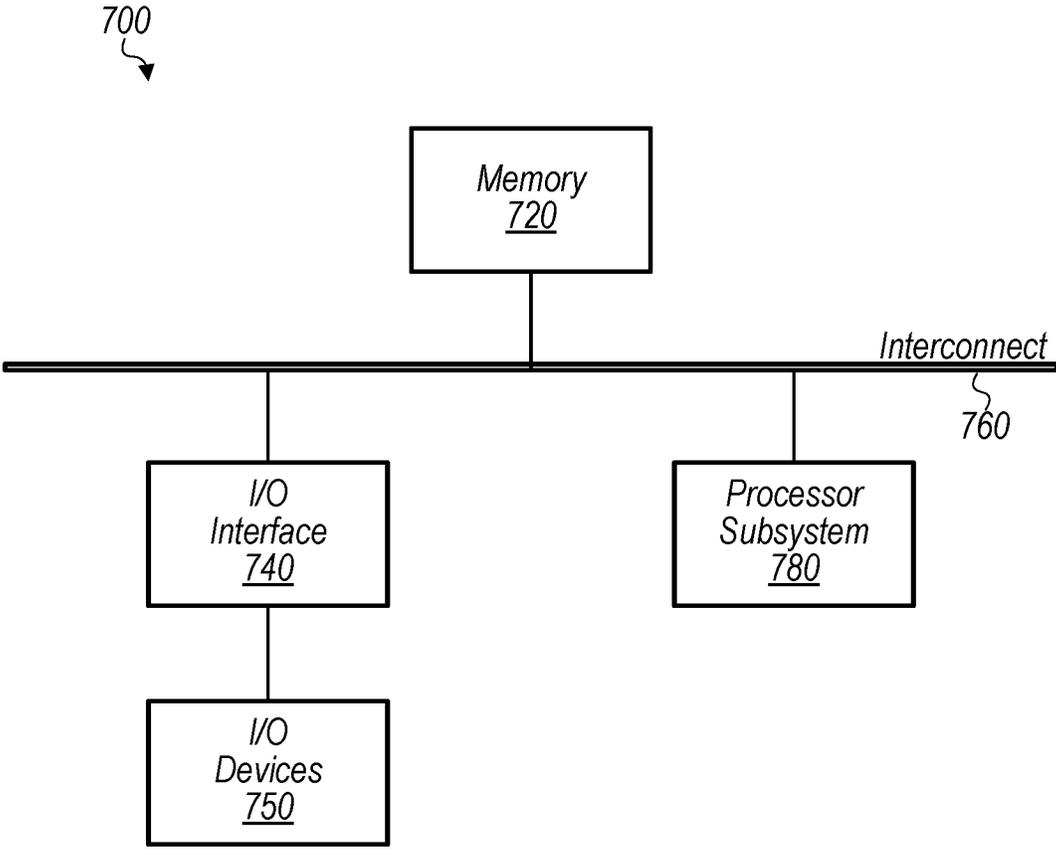


FIG. 7

**PAIRING DEVICES BASED ON DISTANCE**

The present application is a continuation of U.S. application Ser. No. 16/835,057, entitled “PAIRING DEVICES BASED ON DISTANCE,” filed Mar. 30, 2020, which claims priority to U.S. Provisional App. No. 62/835,216, entitled “PAIRING DEVICES BASED ON DISTANCE,” filed Apr. 17, 2019; the disclosures of each of the above-referenced applications are incorporated by reference herein in their entireties.

**BACKGROUND****Technical Field**

This disclosure relates generally to secure communication between computer systems, and more particularly to devices pairing with each other.

**Description of the Related Art**

Communications between different computer systems can be encrypted with a cryptographic key to ensure the security of such communication. In many security protocols, the encryption key is either shared between the two computer systems and/or mutually generated from information available to both computer systems. Before completing the process of setting up a communications link between each other, however, in many security protocols, the two computer systems first verify that their interlocutor is authentic. Moreover, once the communications link is established, many security protocols require that the devices confirm a command to establish communications such as with a shared password or code such that unintentional or fraudulent attempts to establish communications are stopped.

**SUMMARY**

The present disclosure concerns pairing between two devices such that the two devices can exchange messages with one another after the pairing operation is completed. One of these devices, a pairing initiator device, receives a command from a user to pair with the other device, a pairing responder device. The pairing initiator device initiates the pairing operation by communicating with the pairing responder device. After a determination is made as to the authenticity of the pairing responder device, the pairing initiator device and pairing responder device exchange communications to range with each other to determine a distance between the pairing initiator device and pairing responder device. Based on the distance being below a threshold, the pairing initiator device and pairing responder device wirelessly pair with each other without further input from the user beyond the command to pair that initiated the pairing operation.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a block diagram illustrating communication between a pairing initiator device and a pairing responder device in accordance with various embodiments.

FIG. 2 is an expanded block diagram of the pairing initiator device of FIG. 1 in accordance with various embodiments.

FIG. 3 is an expanded block diagram of the pairing responder device of FIG. 1 in accordance with various embodiments.

FIG. 4A is a flowchart illustrating an embodiment of a pairing and ranging method in accordance with the disclosed embodiments.

FIG. 4B is a flowchart illustrating an alternate embodiment of a pairing and ranging method in accordance with the disclosed embodiments.

FIG. 5 is a flowchart illustrating an embodiment of a pairing and ranging method in accordance with the disclosed embodiments.

FIG. 6 is a flowchart illustrating an embodiment of a pairing and ranging method in accordance with the disclosed embodiments.

FIG. 7 is a block diagram of an exemplary computer system, which may implement the various components of FIGS. 1, 2, and 3.

This disclosure includes references to “one embodiment” or “an embodiment.” The appearances of the phrases “in one embodiment” or “in an embodiment” do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

Within this disclosure, different entities (which may variously be referred to as “units,” “circuits,” other components, etc.) may be described or claimed as “configured” to perform one or more tasks or operations. This formulation—[entity] configured to [perform one or more tasks]—is used herein to refer to structure (i.e., something physical, such as an electronic circuit). More specifically, this formulation is used to indicate that this structure is arranged to perform the one or more tasks during operation. A structure can be said to be “configured to” perform some task even if the structure is not currently being operated. A “computer system configured to receive a command” is intended to cover, for example, a computer system has circuitry that performs this function during operation, even if the computer system in question is not currently being used (e.g., a power supply is not connected to it). Thus, an entity described or recited as “configured to” perform some task refers to something physical, such as a device, circuit, memory storing program instructions executable to implement the task, etc. This phrase is not used herein to refer to something intangible. Thus, the “configured to” construct is not used herein to refer to a software entity such as an application programming interface (API).

The term “configured to” is not intended to mean “configurable to.” An unprogrammed FPGA, for example, would not be considered to be “configured to” perform some specific function, although it may be “configurable to” perform that function and may be “configured to” perform the function after programming.

Reciting in the appended claims that a structure is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. § 112(f) for that claim element. Accordingly, none of the claims in this application as filed are intended to be interpreted as having means-plus-function elements. Should Applicant wish to invoke Section 112(f) during prosecution, it will recite claim elements using the “means for” [performing a function] construct.

As used herein, the terms “first,” “second,” etc. are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.) unless specifically stated. For example, references to “first” and “second” devices would not imply an ordering between the two unless otherwise stated.

As used herein, the term “based on” is used to describe one or more factors that affect a determination. This term does not foreclose the possibility that additional factors may

affect a determination. That is, a determination may be solely based on specified factors or based on the specified factors as well as other, unspecified factors. Consider the phrase “determine A based on B.” This phrase specifies that B is a factor is used to determine A or that affects the determination of A. This phrase does not foreclose that the determination of A may also be based on some other factor, such as C. This phrase is also intended to cover an embodiment in which A is determined based solely on B. As used herein, the phrase “based on” is thus synonymous with the phrase “based at least in part on.”

As used herein, the word “module” refers to structure that stores or executes a set of operations. A module refers to hardware that implements the set of operations, or a memory storing the set of instructions such that, when executed by one or more processors of a computer system, cause the computer system to perform the set of operations. A module may thus include an application-specific integrated circuit implementing the instructions, a memory storing the instructions and one or more processors executing said instructions, or a combination of both.

#### DETAILED DESCRIPTION

Referring now to FIG. 1, a block diagram illustrating communication between a pairing initiator device 110 and a pairing responder device 120 is depicted. Pairing initiator device 110 receives a command 142 to pair with pairing responder device 120 from a user 140. Pairing initiator device 110 and pairing responder device 120 engage in various communications 144 relating to a pairing operation and various communications 146 relating to a ranging operation as discussed herein. In various embodiments, pairing initiator device 110 communicates with an authentication computer system 130 as part of the pairing operation. Commonly, the establishing of a communications connection between two different computer system is referred to as “pairing” such that when two devices are set up to communicate with one another, they are “paired.” In various embodiments, after the pairing process is completed both of the paired devices will have the other’s connection information. Such information may include, but is not limited to, one or more identifiers of the interlocutor device (e.g., a name, a MAC address, an IP address, etc.), one or more encryption keys used to secure communications between the paired devices, certificates associated with the interlocutor device, etc. In various embodiments, the pairing process includes negotiating one or more encryption keys used to secure communications between the paired devices.

Pairing initiator device 110 is one or more computer systems that communicates, pairs, and/or ranges with pairing responder device 120 as discussed herein. In various embodiments, pairing initiator device 110 communicates with authentication computer system 130 as discussed herein. In various embodiments, pairing initiator device 110 is remote from authentication computer system 130 and is disposed Distance A from pairing responder device 120. In various embodiments, pairing initiator device 110 and pairing responder device 120 communicate via a wireless (e.g., Bluetooth, Wi-Fi, Zigbee, Ultra-wideband) and/or wired communications medium. In various embodiments, pairing initiator device 110 is a mobile device including but not limited to a mobile phone, a tablet computer, a laptop computer, a wearable computer (e.g., smartwatch, smart glasses). In various embodiments, pairing initiator device 110 receives command 142 and in response attempts to pair and/or range with pairing responder device 120. The pairing

initiator device 110 may also be referred to herein as the “first device,” while the pairing responder device 120 may be referred to as the “second device.” However, no ordering of these devices is implied. Moreover, while the pairing initiator device 110 is referred to herein as the “initiator,” in various embodiments the “responder” may in fact send a message to pairing initiator device 110 first (e.g., via a broadcast ready-to-pair message). Pairing initiator device 110 is referred to herein as the “initiator” within the meaning of this disclosure because pairing initiator device 110 is the device that receives command 142 from the user. In various embodiments, pairing initiator device 110 includes one or more cryptographic circuits 112, one or more transceivers 114, and one or more user interfaces 116. Pairing initiator device 110 is discussed in further detail herein in reference to FIG. 2.

Pairing responder device 120 is one or more computer systems that communicates, pairs, and/or ranges with pairing initiator device 110 as discussed herein. In various embodiments, pairing responder device 120 communicates with authentication computer system 130 as discussed herein. In various embodiments, pairing responder device 120 is remote from authentication computer system 130 and is disposed Distance A from pairing initiator device 110. In various embodiments, pairing initiator device 110 and pairing responder device 120 communicate via a wireless (e.g., Bluetooth, Wi-Fi, Zigbee, Ultra-wideband) and/or wired communications medium. In various embodiments, pairing responder device 120 is any of a number of devices that can pair with pairing initiator device 110 included but not limited to a mobile phone, a tablet computer, a laptop computer, a wearable computer (e.g., smartwatch, smart glasses), a smart home device (e.g., an APPLE HOMEPOD®), a tracking and location device, wireless headphones, a wireless headset, a wireless speaker, a wireless game or media controller, etc. In various embodiments, pairing responder device 120 includes one or more cryptographic circuits 122 and one or more transceivers 124. Pairing responder device 120 is discussed in further detail herein in reference to FIG. 3.

In various embodiments, authentication computer system 130 is one or more computer systems with pairing initiator device 110 and/or pairing responder device 120. In such embodiments, authentication computer system 130 is remote from pairing initiator device 110 and/or pairing responder device 120. In various other embodiments, however, pairing initiator device 110 and pairing responder device 120 are able to pair and range as discussed herein without either communicating with authentication computer system 130. In various embodiments, authentication computer system 130 is configured to verify the authenticity of pairing initiator device 110 and/or pairing responder device 120. In some of such embodiments, authentication computer system 130 receives, verifies, signs, and/or sends cryptographic information such that the authentication computer system 130 is able to determine whether pairing initiator device 110 and/or pairing responder device 120 is authentic. For example, in various embodiments, authentication computer system 130 is configured to receive cryptographic information generated by pairing responder device 120 and sent to authentication computer system 130 by pairing initiator device 110 (e.g., the cryptographic indicator 406 discussed in connection to FIG. 4 herein), process the received cryptographic information, and determine the authenticity of pairing responder device 120. In various embodiments, authentication computer system 130 is an attestation server (or attestation computer system) that provides an attestation of the authen-

ticity of pairing initiator device 110 to pairing responder device 120 or vice versa. In various embodiments, authentication computer system 130 includes a manufacturer's privacy certificate authority or a third-party privacy certificate authority. The actions performed by authentication computer system 130 are discussed in further detail herein in reference to FIG. 4.

In various embodiments, user 140 is a natural person who has access to pairing initiator device 110. As discussed herein in further detail with reference to FIGS. 2 and 4, user 140 inputs command 142 to pairing initiator device 110 which pairs and ranges with pairing responder device 120. In various embodiments, after user 140 has input command 142, pairing initiator device 110 and pairing responder device 120 become wirelessly paired without further input from the user. In some instances, user 140 is prompted to bring pairing initiator device 110 within a threshold distance of pairing responder device 120 (e.g., distance prompt 424 discussed in connection with FIG. 4). In some embodiments, user 140 receives a user notification 430 indicating the result of the pairing operation (e.g., success, failure, error).

In various embodiments, pairing initiator device 110 and pairing responder device 120 exchange communications 144 relating to a pairing operation and various communications 146 relating to a ranging operation as discussed herein. These communications are discussed in further detail in reference to FIG. 4. In various embodiments, after receiving command 142, pairing initiator device 110 and pairing responder device 120 exchange various communications 144 to negotiate one or more cryptographic keys to secure communications 144 and exchange connection information with one another to facilitate the pairing process. In various embodiments, pairing initiator device 110 and pairing responder device 120 exchange various communications 146 (e.g., using transceivers 112 and 122) to range with each other and determine a Distance A between pairing responder device 120 and pairing initiator device 110. As discussed herein, based on Distance A being below a threshold distance, wirelessly pairing the pairing responder device 120 with the pairing initiator device 110 without further input from user 140. As used herein, this "input" from user 140 refers to any input to pairing initiator device 110 or pairing responder device 120 that is received via a user interface of either of those devices. In various embodiments, user 140 may be prompted to bring pairing initiator device 110 within the threshold distance from pairing responder device 120, but in such embodiments user 140 does not need to actually input information into pairing initiator device 110 (e.g., by pressing a button, by tapping a touchscreen) to complete the pairing operation discussed herein. Accordingly, as described and claimed herein, a user who physically moves a pairing initiator device 110 or pairing responder device 120 closer to the other to bring them within a threshold distance to complete the pairing operation (e.g., in response to a distance prompt 424 discussed in connection to FIG. 4) has not provided any "input" to the moved device 110 or 120 in order to complete the pairing operation after inputting command 142.

Accordingly, in various embodiments, user 140 is able to effectuate pairing between pairing initiator device 110 and pairing responder device 120 with a single input to only one of the devices 110 or 120 (i.e., command 142 to pairing initiator device 110). Because the confirmation of the intent to pair is inferred because the distance between the two devices 110 and 120 is below a threshold in various embodiments, the disclosed techniques allow user 140 to securely pair devices 110 and 120 with minimal interaction with one

device and potentially no interaction with the other. As discussed herein in further detail in connection to FIG. 4, the threshold distance can be any appropriate distance, but in various embodiments is between 10 cm and 50 cm (e.g., 15 cm plus or minus 5 cm). In such embodiments, a confirmation of intent to pair can be inferred by the devices 110 and 120 being close together, which eliminates the need to, for example, additionally input a passcode on either device 110 or 120. In instances where pairing responder device 120 has limited input capabilities (e.g., not having a display, not having buttons), user 140 is thus able to pair the device 110 and 120 without a potentially cumbersome interaction with a pairing responder device 120 with limited input capabilities. Additionally, in some embodiments, the techniques disclosed herein may be used to further secure pairing between devices 110, 120 that receive user input to confirm the intent to pair devices 110 and 120. In such embodiments, determining the distance between devices 110 and 120 as discussed herein provides additional confirmation of intent to pair and/or to further protect from accidental or malicious pairing requests. Moreover, by leveraging the cryptographic circuits 112 and 122 to secure communications 144 and 146 (and in various embodiments communicating with authentication computer system 130), further security may be provided in various embodiments. Accordingly, a malicious device attempting to pair with pairing initiator device 110 would have to (a) be physically near pairing initiator device 110 and (b) be able to generate cryptographic information that appears authentic to pairing initiator device 110 and/or authentication computer system 130.

FIGS. 2 and 3 depict expanded block diagrams of pairing initiator device 110 and pairing responder device 120, respectively. Referring now to FIG. 2, an expanded block diagram of pairing initiator device 110 is depicted. In various embodiments, pairing initiator device 110 includes cryptographic circuit 112, transceiver 114, user interface 116, and one or more public keys 204. Referring now to FIG. 3, an expanded block diagram of pairing responder device 120 is depicted. As shown in FIG. 3, pairing responder device 120 includes cryptographic circuit 122, transceiver 124, one or more public keys 304, and user interface 306. In various embodiments, various components of pairing initiator device 110 and pairing responder device 120 shown in FIGS. 2 and 3 are optional. For example, in various embodiments, mailboxes 202 and 302 and/or user interface 306 are omitted.

In various embodiments, cryptographic circuits 112 and 122 are computing devices that comprise a key generation module that can generate cryptographic information useable to secure the pairing and ranging processes disclosed herein. Each cryptographic circuit 112 and 122 has a respective, unique identifier: an initiator unique identifier 200 and a responder unique identifier 300. In various embodiments, either or both cryptographic circuit 112 or 122 includes a mailbox (i.e., a mailbox 202 and a mailbox 302, respectively). In some embodiments, cryptographic circuits 112 and 122 are implemented using the same (or similar) hardware, software, and firmware and only materially differ by having different unique identifiers 200, 300. In other embodiments, however, the cryptographic circuits 112 and 122 differ by, for example, (a) one being optimized for low power consumption for use in a battery-powered device with the other being optimized for use in a device drawing power from a power grid, (b) one being designed with stricter security parameters than the other, and/or (c) one having greater amounts of memory or processing speed than the other. In various embodiments, cryptographic circuits 112 or

**122** are secure enclave processors (SEP). In various embodiments, cryptographic circuits **112** or **122** include one or more components that are walled off from access by other components of the device **110** or **120** in which the cryptographic circuits **112** or **122** are installed (e.g., through the use of a mailbox **202** or **302** discussed herein).

In various embodiments, cryptographic circuits **112** and **122** are configured to generate one or more hardware reference keys (HRK) for use by the pairing initiator device **110** or pairing responder device **120**, respectively. In some embodiments, cryptographic circuits **112** and **122** are configured to generate one or more hardware reference key attestations (HKRA) that attest to the authenticity of the hardware reference keys generated, and are useable (e.g., by authentication computer system **130**) to verify the authenticity of the pairing initiator device **110** or pairing responder device **120** as discussed herein. In various embodiments, the HRK can be an asymmetric key pair, having a private key and a public key portion. The HRKA can identify information about the cryptographic circuits **112** and **122** (and/or pairing initiator device **110** or pairing responder device **120**) such as the operating system version running on the cryptographic circuits **112** and **122**, the make and model of the pairing initiator device **110** or pairing responder device **120**, the serial number of the pairing initiator device **110** or pairing responder device **120**, etc. In various embodiments, the cryptographic circuits **112** and **122** comprise secure portions of a system on a chip.

In various embodiments, the HRKA is cryptographic indicator (e.g., a cryptographic indicator **406** discussed in connection to FIG. 4). The HRKA can attest to the processing system classification (e.g. a processor type such as the Apple® A9) that was running on the cryptographic circuits **112** or **122** at the time that the HRK was generated. The HRKA can further attest to the version of an operating system (e.g., secure enclave processor operating system, SEP OS) that was running on the cryptographic circuits **112** or **122** at the time that the HRK was generated. The HRKA can be sent to authentication computer system **130** as discussed herein. In such embodiments, authentication computer system **130** stores sufficient information to verify that an HRKA attesting to an HRK was in fact generated by the pairing initiator device **110** or pairing responder device **120** that generated the HRK. As discussed herein, authentication computer system **130** can then generate a certificate (e.g., the authentication indicator **408** discussed in connection to FIG. 4) and return the certificate to the pairing initiator device **110** or pairing responder device **120** for use in the pairing and/or ranging processes discussed herein.

In various embodiments, cryptographic circuits **112** and **122** include respective unique identifiers **200**, **300**. In various embodiments each of unique identifiers **200**, **300** uniquely identifies the cryptographic circuits **112** or **122** within pairing initiator device **110** or pairing responder device **120**. As discussed herein, authentication computer system **130** stores copies of the unique identifiers **200**, **300** or indicators derived from the unique identifiers **200**, **300** (e.g., cryptographic keys or certificates generated using the unique identifiers **200**, **300**). Such information may be, for example, obtained during the manufacturing process of cryptographic circuits **112** and **122**. In various embodiments, unique identifiers **200**, **300** are used by their respective cryptographic circuits **112**, **122** to generate one or more cryptographic indicators (e.g., a HRK, a HKRA) and/or shared ranging keys. In various embodiments, the cryptographic circuits **112**, **122** store their respective unique identifiers **200**, **300** in secure memory (e.g., one or more regis-

ters) within cryptographic circuits **112**, **122** that is walled off from access by other components of the device **110** or **120**. In various embodiments, the content of such secure memory is set during the manufacture of cryptographic circuits **112**, **122**. In some embodiments, the unique identifiers **200**, **300** are permanently set (e.g., by burning a sequence of fuses) during manufacture. In other embodiments, unique identifiers **200**, **300** become set as a result of random variation in the manufacturing process.

As discussed herein, pairing initiator device **110** and pairing responder device **120** are configured to generate a shared ranging key based on cryptographic identities (e.g., unique identifiers **200**, **300**) of the pairing initiator device and the pairing responder device in various embodiments. This shared ranging key is used by the transceiver **114**, **124** to secure ranging communications (e.g., by encrypting such communications, by generating unpredictable wireless transmissions). In various embodiments, unique identifiers **200**, **300** are used to facilitate a cryptographic key exchange protocol to agree on a symmetric shared ranging key (e.g., a SIGMA protocol, a Diffie-Hellman key exchange). As discussed herein in reference to FIG. 4 during key negotiation **404**, pairing initiator device **110** and pairing responder device **120** are configured to generate private-public key pairs in which the public key is shared with the interlocutor such that each has its own private key and the public key of the other (e.g., one of the public keys **204**, **304**). Using its own private key and the other's public key, both the pairing initiator device **110** and pairing responder device **120** are thus able to mutually derive the same shared ranging key. Similarly, unique identifiers **200**, **300** are used to facilitate a cryptographic key exchange protocol to agree on a symmetric shared communications key to encrypt communications during the pairing operation and after pairing is complete. In various embodiments, the shared ranging key and the shared communications key are different but are separately derived from the same key.

In various embodiments, the cryptographic circuits **112** and **122** include respective mailboxes **202**, **302**. In such embodiments, the internal components of cryptographic circuits **112**, **122** are not accessible from outside the cryptographic circuits **112**, **122**. In such embodiments, the internal components of the cryptographic circuits **112**, **122** are hardware-isolated from other computing components of the device **110** or **120** by the mailbox **202**, **302**. In such embodiments, information may be sent from cryptographic circuit **112**, **122** to the rest of device **110**, **120** via mailbox **202**, **302**, respectively. Similarly, information may be passed from device **110**, **120** to its cryptographic circuit **112**, **122** via mailbox **202**, **302**, respectively. Mailboxes **202**, **302** are optional components in various embodiments such that neither, either, or both of pairing initiator device **110** and pairing responder device **120** may include a mailbox **202**, **302** in various embodiments.

In various embodiments, public keys **204**, **304** are any of a number of public keys stored by respective pairing initiator device **110** and pairing responder device **120**. As discussed herein, pairing initiator device **110** stores a public key **204** corresponding to pairing responder device **120** in various embodiments. Similarly, pairing responder device **120** stores a public key **304** corresponding to pairing initiator device **110** in various embodiments. Moreover, in various embodiments, either or both of pairing initiator device **110** and pairing responder device **120** store a public key **204**, **304** corresponding to authentication computer system **130**. Such public keys **204**, **304** corresponding to authentication computer system **130** are useable to verify authentication indi-

cators from authentication computer system **130** (e.g., authentication indicator **408** referred to in FIG. 4) as discussed herein.

Transceiver **114**, **124** can be any of a number of wired and/or wireless transmitters and receivers usable to range as discussed herein. In various embodiments, transceiver **114**, **124** is a Bluetooth® transceiver. In various embodiments, pairing initiator device **110** and/or pairing responder device **120** include one or more other wired and/or wireless communications modules (not shown). For example, pairing initiator device **110** and/or pairing responder device **120** may include a cellular communications module, an IEEE **802.11** wireless communications module, a GPS receiver, a near-field communications module, or any combination thereof. In such embodiments, the pairing initiator device **110** and/or pairing responder device **120** can use these communications modules to communicate with other devices (e.g., authentication computer system **130**) over various networks (e.g., the Internet). As discussed herein, in some embodiments, pairing responder device **120**, however, has no capability to access the Internet directly and uses pairing initiator device **110** as an intermediary. In other embodiments, however, pairing responder device **120** has its own networking capability and can access other devices (e.g., authentication computer system **130**) independent of pairing initiator device **110**. In some of such embodiments, though, pairing responder device **120** is not configured to communicate with authentication computer system **130** prior to the pairing operation. This can be, for example, because the communications capability of pairing responder device **120** requires information to access the Internet (e.g., pairing responder device **120** does not have the SSID and passkey for access to a local wireless network). In such embodiments, pairing responder device **120** can receive configuration commands and/or instructions from pairing initiator device **110** after pairing as discussed herein with reference to FIG. 4.

In various embodiments, pairing initiator device **110** and/or pairing responder device **120** include respective user interfaces **116**, **306**. In various embodiments, user interfaces **116**, **306** are any of a number of devices configured to present information to user **140** and/or receive information from user **140** (e.g., command **142**). Such devices include but are not limited to any number of displays or light arrays, graphical user interfaces presented via touchscreen, keyboards, buttons, microphones, speakers, haptic interfaces, motion sensors, cameras, etc. It will be understood that the format of command **142** will depend on the type of user interface **116** used to receive command **142**. For example, in embodiments where user interface **116** is a touchscreen, command **142** comprises one or more touches on buttons or icons on a graphical user interface presented on the touchscreen. In other embodiments, command **142** may be an audible command received by a microphone, a gesture received by a camera, a shake received via one or more accelerometers, etc.

In various embodiments, pairing responder device **120** does not include a user interface **306** and is therefore incapable of directly receiving information from user **140** and/or presenting information to user **140**. In other embodiments, pairing responder device **120** includes a user interface **306**, but such user interface **306** is configured only to present limited information and to receive only limited information from user **140**. As a non-limiting example, in embodiments where pairing responder device **120** is a location tracking device, user interface **306** consists of a button to activate the location tracking features of the device (e.g., sending a signal to locate a misplaced pairing initiator

device **110** after pairing) and a light to indicate to user **140** that the location tracking feature has been activated. But, in such an embodiment, however, user interface **306** is not configured to receive, for example, a command from user **140** confirming an intent to pair with pairing initiator device **110**.

In various embodiments, pairing responder device **120** broadcasts a “pairing available” message (e.g., using transceiver **124**) in anticipation that a pairing initiator device **110** might attempt to pair with pairing responder device **110**. In such embodiments, pairing initiator device **110** is configured to detect pairing responder device **120**, and based on the detecting, prompt user **140** with a message asking whether to input command **142** to wirelessly pair with pairing responder device **120**. As discussed herein, upon receiving command **142** to wirelessly pair with the pairing responder device, pairing initiator device **110** sends, to the pairing responder device, a request to wirelessly pair with pairing responder device **120**.

FIGS. 4A, 4B, 5, and 6 illustrate various flowcharts representing various disclosed methods implemented with the components depicted in FIG. 1. Referring now to FIG. 4A, a flowchart illustrating an embodiment of a pairing and ranging method **400** is shown. In the embodiment shown in FIG. 4A, the various actions associated with method **400** are implemented by pairing initiator device **110**, pairing responder device **120**, and authentication computer system **130** while receiving input from (and in some embodiments providing output to) user **140**.

In various embodiments, method **400** is initiated by user **140** entering command **142** to pairing initiator device **110** (e.g., by tapping a touchscreen of user interface **116**). In response to command **142**, pairing initiator device **110** sends a request to pair **402** to pairing responder device **120**.

During key negotiation **404**, pairing initiator device **110** and pairing responder device **120** negotiate a shared communications key and/or shared ranging key (e.g., using cryptographic circuits **112** and **122** as discussed herein). In some embodiments, both pairing initiator device **110** and pairing responder device **120** mutually generate a shared key using a cryptographic protocol, but in other embodiments negotiation includes determining which of a set of predetermined keys to use or simply sending the key from one device to the other.

Subsequent to key negotiation **404**, pairing responder device **120** sends cryptographic indicator **406** to pairing initiator device **110** for retransmission to authentication computer system **130** in various embodiments (e.g., embodiments in which pairing responder device **120** lacks capability to directly communicate with authentication computer system **130** due to a lack of hardware or lack of configuration). In turn, pairing initiator device **110** receives cryptographic indicator **406** and sends it along to authentication computer system **130**. In other embodiments, pairing initiator device **110** is configured to authenticate cryptographic indicator **406** itself (i.e., without sending it to authentication computer system **130**). In still other embodiments, pairing responder device **120** is configured to send cryptographic indicator **406** to authentication computer system **130** directly. As discussed herein, cryptographic indicator **406** is generated by pairing responder device **120** (e.g., using cryptographic circuit **122**) and is useable by an attestation server (e.g., authentication computer system **130**) to authenticate pairing responder device **120**. In various embodiments, cryptographic indicator **406** is a HRKA or other attestation of the authenticity of pairing responder device discussed with reference to FIGS. 2 and 3 herein.

11

After receiving cryptographic indicator **406**, authentication computer system **130** determines the authenticity of pairing responder device **120** according to one or more cryptographic techniques. For example, authentication computer system **130** can receive cryptographic indicator **406** and determine that it (or one or more values derived from it) match a stored value (e.g., the unique identifier **300** stored during the manufacture of pairing responder device **120**, a value that was calculated from unique identifier **300**, etc.) in various embodiments. Upon determining the authenticity of pairing responder device **120**, authentication computer system **130** sends an authentication indicator **408** of the authenticity of the pairing responder device **120** to pairing initiator device **110**. In various embodiments, authentication indicator **408** is an attestation indicator that proves that the authentication computer system **130** determined that cryptographic indicator **406** is a valid attestation of the authenticity of pairing responder device **120**. In various other embodiments, no authentication computer system **130** is present and pairing initiator device **110** authenticates pairing responder device **120** itself. In some of such embodiments, both pairing initiator device **110** and pairing responder device **120** have copies of a symmetric key (e.g., a symmetric key shared with both devices **110**, **120** when they were manufactured). In various embodiments, the symmetric key is used to facilitate a cryptographic key exchange or cryptographic key derivation to agree on a symmetric shared ranging key between pairing initiator device **110** and pairing responder device **120**.

Based on pairing initiator device **110** receiving (and in embodiments verifying) authentication indicator **408** (or in some embodiments authenticating pairing responder device **120** directly), pairing initiator device **110** continues with the ranging and pairing operations continue as discussed further herein. In other embodiments, pairing initiator device **110** receives an authentication failure indicator from authentication computer system **130** (or does not receive any response at all). In such embodiments, pairing initiator device **110** aborts the pairing operation (and does not begin the ranging operation) based on either receiving an authentication failure indicator or by an amount of time expiring without receiving a response from authentication computer system **130**.

In various embodiments, pairing initiator device **110** verifies the received authentication indicator **408** at block **410**. In such embodiments, pairing initiator device **110** may verify the authentication indicator **408** using any of a number of cryptographic techniques. For example, in some embodiments, authentication indicator **408** is a certificate that is verified using one or more values included with authentication indicator **408**. In such embodiments, completing the pairing operation is conditioned on successfully verifying authentication indicator **408** (e.g., the pairing process is aborted if authentication indicator **408** is not successfully verified).

Upon receiving (and in various embodiments verifying) authentication indicator **408**, pairing initiator device **110** sends an acknowledgement **412** of authentication (or in embodiments, attestation) based on authentication indicator **408** received from authentication computer system **130**. In various embodiments, acknowledgement **412** provides notice to pairing responder device **120** to begin ranging (either immediately, or after the expiration of a timer). In other embodiments, acknowledgement **412** includes additional information to be used in the ranging operation (e.g., a channel on which to range, an additional key to secure ranging, an indication of the threshold maximum distance to finish pairing).

12

At blocks **420**, pairing initiator device **110** and pairing responder device **120** exchange various ranging communications **422** to determine the distance (i.e., Distance A) between pairing initiator device **110** and pairing responder device **120**. In various embodiments, communications **422** are secured (e.g., encrypted, signed and encrypted) using a shared ranging key (and in embodiments a certificate from the device **110**, or **120** sending a particular communication **422**). In various embodiments, the ranging operation includes device **110** and **120** synchronizing one or more clocks. In such embodiments, a device **110** or **120** sends a first communication **422** to the other noting the time the first communication **422** is sent, and the interlocutor responds with a second communication **422** indicating the time the first communication was received. The difference between the two times can therefore be used to estimate the distance (over a wire for wired communication or through space for wireless communication) between the devices **110** and **120**. In other embodiments, other ranging techniques may be used to estimate the distance between devices **110** and **120**.

In various embodiments, the ranging operation includes sending a distance prompt **424** to user **140** to bring pairing initiator device **110** within the threshold distance from pairing responder device **120**. In various embodiments, the ranging operation occurs on a regular basis for a period of time such that the devices **110** and **120** regularly (or continuously) range with one another such that the ranging operation continues without input from user **140**.

At block **426**, pairing initiator device **110** and pairing responder device **120** complete the pairing operation based the Distance A being below a threshold distance. In various embodiments, the threshold distance is between 10 cm and 50 cm (although other distances can be used). In some of such embodiments, for example, the distance is 15 cm plus or minus 5 cm. In various embodiments, the threshold distance is a relatively close distance to avoid mistaken or fraudulent pairing. When mistaken or fraudulent pairing is less of a concern, however (e.g., in a physically secure area like a private corporate or government facility), the threshold distance can be relatively large and limited only by the maximum transmission range of transceivers **114**, **124**. In other instances, however, if Distance A is not under the threshold distance after a period of time (e.g., 2 minutes, but any time could be used) the pairing process times out and is cancelled in various embodiments.

After pairing initiator device **110** and pairing responder device **120** have successfully paired, user **140** may be sent a user notification **430** (e.g., presented on user interface **116**) in various embodiments. In some embodiments, subsequent to wirelessly pairing, pairing initiator device **110** sends on or more configuration messages **432** to pairing responder device **120**. Such configuration messages **432** can include, for example, instructions to configure pairing responder device **120** (i.e., optional information that pairing responder device **120** may use to configure itself depending on settings on pairing responder device **120**) or commands to configure pairing responder device **120** (i.e., mandatory information that pairing responder device **120** uses to configure itself). After receiving such configuration messages **432**, pairing responder device **120** changes one or more of its settings based on such configuration messages **432**. In a first example, pairing responder device **120** is not configured to directly communicate (i.e., not using pairing initiator device **110** as an intermediary) with authentication computer system **130** (or with the Internet more broadly) prior to the pairing operation. Configuration messages **432**, however, provide configuration settings necessary to communicate

with authentication computer system 130 and/or the Internet (e.g., a wireless network name and passkey, cellular communications settings).

Referring now to FIG. 4B, a flowchart illustrating an alternate embodiment of a pairing and ranging method 440 is shown. In the embodiment shown in FIG. 4B, the various actions associated with method 440 are implemented by pairing initiator device 110, pairing responder device 120, and authentication computer system 130 while receiving input from (and in some embodiments providing output to) user 140.

In various embodiments, the pairing process discussed herein is initiated and completed without either pairing initiator device 110 or pairing responder device 120 communicating with authentication computer system 130. In some of such embodiments, neither of pairing initiator device 110 or pairing responder device 120 communicate with any other computer system during the pairing process (e.g., neither pairing initiator device 110 or pairing responder device 120 have access to the Internet). In such embodiments, pairing initiator device 110 and authentication computer system 130 engage in key co-signing 434 prior to the pairing process being initiated. For example, in various embodiments, key co-signing 434 is performed a few hours before the pairing process is performed. In key co-signing 434, pairing initiator device 110 sends a cryptographic indicator (e.g., a token signed with a private key of pairing initiator device 110) to authentication computer system 130, authentication computer system 130 authenticates the cryptographic indicator (e.g., using a public key associated with pairing initiator device 110), and then authentication computer system 130 co-signs the cryptographic indicator using a private key associated with authentication computer system 130. The co-signed cryptographic indicator 436 is then sent to pairing initiator device 110 for use in the pairing process. In some of such embodiments, pairing initiator device 110 sends the co-signed cryptographic indicator 436 to pairing responder device 120 during key negotiation 404. Pairing responder device 120 then verifies the co-signed cryptographic indicator 436 using a public key associated with authentication computer system 130 at block 438. Then, pairing responder device 120 sends its cryptographic indicator 406 to pairing initiator device 110. Pairing initiator device 110 then verifies the pairing cryptographic indicator 406 at block 410. The method 440 then proceeds in the same manner as method 400 discussed in reference to FIG. 4A.

Referring again to FIGS. 4A and 4B, as discussed herein, methods 400 and 440 allow user 140 to securely effectuate pairing between two devices with minimal input from user 140 (i.e., only command 142 to pairing initiator device 110). In various embodiments, user 140 provides no input at all to pairing responder device 120. Indeed, in various embodiments, pairing responder device 120 lacks a user interface 306 is therefore incapable of receiving input from user 140, but can be paired with pairing initiator device 110 as discussed herein. As discussed above, user 140 who moves pairing initiator device 110 closer to pairing responder device (or vice versa) has not provided additional input as defined herein, and the only input from user 140 necessary to start and complete the method 400 is command 142. Accordingly, the techniques disclosed herein provide both quality of life improvement to the user experience (i.e., pairing requires minimal user effort and “just works”) without sacrificing security (e.g., because pairing only is completed when devices 110 and 120 are close together, communications between devices 110 and 120 are secured using cryptographic techniques, and authentication computer sys-

tem 130 can verify the authenticity of pairing responder device 120 using previously stored information).

Referring now to FIG. 5 a flowchart illustrating an embodiment of a pairing and ranging method 500 is shown. In various embodiments, the various actions associated with method 500 are performed by pairing initiator device 110. At block 502, pairing initiator device 110 receives, from user 140, a command 142 to wirelessly pair with a pairing responder device 120. At block 504, pairing initiator device 110 ranges, using transceiver 114, with transceiver 124 of pairing responder device 120 to determine a distance between pairing responder device 110 and pairing initiator device 120. At block 506, based on the distance being below a threshold distance, pairing initiator device 110 wirelessly pairs with pairing initiator device 120 without further input from user 140.

Referring now to FIG. 6 a flowchart illustrating an embodiment of a pairing and ranging method 600 is shown. In various embodiments, the various actions associated with method 600 are performed by pairing responder device 120. At block 602, pairing responder device 120 ranges, using transceiver 124, with transceiver 114 of pairing initiator device 110 to determine a distance between pairing responder device 120 and the pairing initiator device 110. At block 604, based on the distance being below a threshold, pairing responder device wirelessly pairs with the pairing initiator device without input from user 140 to pairing responder device 120.

Exemplary Computer System

Turning now to FIG. 7, a block diagram of an exemplary computer system 700—which may implement the various components shown in FIGS. 1, 2, and 3 (e.g., pairing initiator device 110, pairing responder device 120)—is depicted. Computer system 700 includes a processor subsystem 780 that is coupled to a system memory 720 and I/O interface(s) 740 via an interconnect 760 (e.g., a system bus). I/O interface(s) 740 is coupled to one or more I/O devices 750. Computer system 700 may be any of various types of devices, including, but not limited to, a server system, personal computer system, desktop computer, laptop or notebook computer, mainframe computer system, tablet computer, handheld computer, workstation, network computer, a consumer device such as a mobile phone, music player, or personal data assistant (PDA). Although a single computer system 700 is shown in FIG. 7 for convenience, system 700 may also be implemented as two or more computer systems operating together.

Processor subsystem 780 may include one or more processors or processing units. In various embodiments of computer system 700, multiple instances of processor subsystem 780 may be coupled to interconnect 760. In various embodiments, processor subsystem 780 (or each processor unit within 780) may contain a cache or other form of on-board memory.

System memory 720 is usable to store program instructions executable by processor subsystem 780 to cause system 700 perform various operations described herein. System memory 720 may be implemented using different physical memory media, such as hard disk storage, floppy disk storage, removable disk storage, flash memory, random access memory (RAM—SRAM, EDO RAM, SDRAM, DDR SDRAM, RAMBUS RAM, etc.), read only memory (PROM, EEPROM, etc.), and so on. Memory in computer system 700 is not limited to primary storage such as memory 720. Rather, computer system 700 may also include other forms of storage such as cache memory in processor subsystem 780 and secondary storage on I/O Devices 750 (e.g.,

a hard drive, storage array, etc.). In some embodiments, these other forms of storage may also store program instructions executable by processor subsystem **780**.

I/O interfaces **740** may be any of various types of interfaces configured to couple to and communicate with other devices, according to various embodiments. In one embodiment, I/O interface **740** is a bridge chip (e.g., Southbridge) from a front-side to one or more back-side buses. I/O interfaces **740** may be coupled to one or more I/O devices **750** via one or more corresponding buses or other interfaces. Examples of I/O devices **750** include storage devices (hard drive, optical drive, removable flash drive, storage array, SAN, or their associated controller), network interface devices (e.g., to a local or wide-area network), or other devices (e.g., graphics, user interface devices, etc.). In one embodiment, computer system **700** is coupled to a network via a network interface device **750** (e.g., configured to communicate over Wi-Fi, Bluetooth, Ethernet, etc.).

Although specific embodiments have been described above, these embodiments are not intended to limit the scope of the present disclosure, even where only a single embodiment is described with respect to a particular feature. Examples of features provided in the disclosure are intended to be illustrative rather than restrictive unless stated otherwise. The above description is intended to cover such alternatives, modifications, and equivalents as would be apparent to a person skilled in the art having the benefit of this disclosure.

The scope of the present disclosure includes any feature or combination of features disclosed herein (either explicitly or implicitly), or any generalization thereof, whether or not it mitigates any or all of the problems addressed herein. Accordingly, new claims may be formulated during prosecution of this application (or an application claiming priority thereto) to any such combination of features. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the appended claims.

Various embodiments described herein may gather and/or use data available from specific and legitimate sources to improve the delivery to users of invitational content or any other content that may be of interest to them (e.g., content delivered using pairing initiator device **110** and/or pairing responder device **120**). The present disclosure contemplates that, in some instances, this gathered data may include personal information data that uniquely identifies or can be used to identify a specific person. Such personal information data can include demographic data, location-based data, online identifiers, telephone numbers, email addresses, home addresses, data or records relating to a user's health or level of fitness (e.g., vital signs measurements, medication information, exercise information), date of birth, or any other personal information.

The present disclosure recognizes that the use of such personal information data, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to deliver targeted content that may be of greater interest to the user in accordance with their preferences. Accordingly, use of such personal information data enables users to have greater control of the delivered content. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure. For instance, health and fitness data may be used, in accordance with the user's preferences to provide insights

into their general wellness, or may be used as positive feedback to individuals using technology to pursue wellness goals.

The present disclosure contemplates that those entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities would be expected to implement and consistently apply privacy practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining the privacy of users. Such information regarding the use of personal data should be prominently and easily accessible by users, and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate uses only. Further, such collection/sharing should occur only after receiving the consent of the users or other legitimate basis specified in applicable law. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and adapted to applicable laws and standards, including jurisdiction-specific considerations which may serve to impose a higher standard. For instance, in the US, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act (HIPAA); whereas health data in other countries may be subject to other regulations and policies and should be handled accordingly.

Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of advertisement delivery services, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter. In another example, users can select not to provide mood-associated data for targeted content delivery services. In yet another example, users can select to limit the length of time mood-associated data is maintained or entirely block the development of a baseline mood profile. In addition to providing "opt in" and "opt out" options, the present disclosure contemplates providing notifications relating to the access or use of personal information. For instance, a user may be notified upon downloading an app that their personal information data will be accessed and then reminded again just before personal information data is accessed by the app.

Moreover, it is the intent of the present disclosure that personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In addition, and when applicable, including in certain health related applications, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing identifiers, controlling the amount or specificity of data stored (e.g., col-

lecting location data at city level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods such as differential privacy.

Therefore, although the present disclosure may broadly cover use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data. For example, content can be selected and delivered to users based on aggregated non-personal information data or a bare minimum amount of personal information, such as the content being handled only on the user's device or other non-personal information available to the content delivery services.

What is claimed is:

1. A pairing initiator device comprising:
  - a processor circuit; and
  - a memory storing instructions executable by the processor circuit to cause the pairing initiator device to perform operations comprising:
    - receiving, from a user, a command to wirelessly pair with a pairing responder device;
    - sending, to a pairing responder device, a first cryptographic indicator co-signed by the pairing initiator device and an attestation server;
    - receiving, from the pairing responder device, a second cryptographic indicator indicating that the first cryptographic indicator has been verified as authentic; and
    - after verifying the second cryptographic indicator:
      - determining a distance between the pairing responder device and the pairing initiator device; and
      - based on the distance being within a specified range, wirelessly pairing the pairing responder device with the pairing initiator device without further input from the user.
2. The pairing initiator device of claim 1, further comprising a transceiver configured to determine the distance between the pairing responder device and the pairing initiator device.
3. The pairing initiator device of claim 1, wherein the first cryptographic indicator is co-signed with a private key of the pairing initiator device and with a private key of the attestation server.
4. The pairing initiator device of claim 1, wherein the pairing initiator device is configured to verify the second cryptographic indicator using a symmetric key shared with the pairing responder device.
5. The pairing initiator device of claim 1, wherein the specified range is between 10 cm and 50 cm.
6. The pairing initiator device of claim 1, wherein the first cryptographic indicator is a hardware reference key attestation (HRKA) attesting to an attribute of the pairing initiator device.
7. The pairing initiator device of claim 1, wherein the pairing initiator device is configured to perform key negotiation with the pairing responder device to generate 1) a shared ranging key for determining the distance between the pairing responder device and the pairing initiator device and 2) a shared communications key for encrypting communications during pairing.

8. A non-transitory computer-readable medium having program instructions stored therein that are executable by a pairing initiator device to perform operations comprising:
  - receiving, from a user, a command to wirelessly pair the pairing initiator device with a pairing responder device;
  - sending, to a pairing responder device, a first cryptographic indicator co-signed by the pairing initiator device and an attestation server;
  - receiving, from the pairing responder device, a second cryptographic indicator indicating that the first cryptographic indicator has been verified as authentic; and
  - after verifying the second cryptographic indicator:
    - determining a distance between the pairing responder device and the pairing initiator device; and
    - based on the distance being within a specified range, wirelessly pairing the pairing responder device with the pairing initiator device without further input from the user.
9. The computer-readable medium of claim 8, wherein the first cryptographic indicator is co-signed with a private key of the pairing initiator device and with a private key of the attestation server.
10. The computer-readable medium of claim 8, wherein the second cryptographic indicator is verified using a symmetric key shared with the pairing responder device.
11. The computer-readable medium of claim 8, wherein the first cryptographic indicator is a hardware reference key attestation (HRKA) attesting to an attribute of the pairing initiator device.
12. The computer-readable medium of claim 8, wherein the pairing initiator device is configured to perform key negotiation with the pairing responder device to generate 1) a shared ranging key for determining the distance between the pairing responder device and the pairing initiator device and 2) a shared communications key to encrypt communications during pairing.
13. A method, comprising:
  - receiving, at a pairing initiator device from a user, a command to wirelessly pair the pairing initiator device with a pairing responder device;
  - sending, by the pairing initiator device to a pairing responder device, a first cryptographic indicator co-signed by the pairing initiator device and an attestation server;
  - receiving, at the pairing initiator device from the pairing responder device, a second cryptographic indicator indicating that the first cryptographic indicator has been verified as authentic; and
  - after verifying the second cryptographic indicator, the pairing initiator device:
    - determining a distance between the pairing responder device and the pairing initiator device; and
    - based on the distance being within a specified range, wirelessly pairing the pairing responder device with the pairing initiator device without further input from the user.
14. The method of claim 13, wherein determining the distance is performed using a transceiver located within the pairing initiator device.
15. The method of claim 13, wherein the first cryptographic indicator is co-signed with a private key of the pairing initiator device and with a private key of the attestation server.
16. The method of claim 13, wherein the pairing initiator device is configured to verify the second cryptographic indicator using a symmetric key shared with the pairing responder device.

17. The method of claim 13, wherein the attestation server includes a certificate authority.

18. The method of claim 13, wherein co-signing of the first cryptographic indicator occurs while the pairing initiator device is connected to the Internet, and wherein the wirelessly pairing occurs when neither the pairing initiator device nor the pairing responder device are connected to the Internet.

19. The method of claim 13, wherein the first cryptographic indicator is verified using a public key associated with the attestation server.

20. The method of claim 13, wherein the method is performed without the user providing any input to the pairing responder device and wherein the wirelessly pairing is performed without the pairing initiator device or the pairing responder device communicating with the attestation server.

\* \* \* \* \*